

# PROCESSING OF THE MACADAMIA



Hawaii Agricultural  
Experiment Station  
Bulletin 83

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# PROCESSING OF THE MACADAMIA

By

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and

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HONOLULU, T. H.  
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The commercial development of the macadamia in Hawaii has led to a study of processing methods adapted to this nut. Since it is marketed principally in cooked, salted-kernel form, processing includes all steps in handling the nut from the time it is harvested until it is packed in the jar. The development of processing methods has resulted from cooperative work by the Hawaii Agricultural Experiment Station and a local macadamia company,<sup>3</sup> carried on over a period of several years. This bulletin describes various experiments conducted and resultant commercial methods which have been adopted. The procedures developed are, in general, similar to those used on other commercial nuts,<sup>4</sup> particularly the almond.

There exist in Hawaii two distinct types of macadamia, the rough-shell (*Macadamia ternifolia*) and the smooth-shell (*Macadamia ternifolia* var. *integrifolia*).<sup>5</sup> As the names suggest, the species and its botanical variety are readily distinguishable, the rough-shell being distinctly knobby and more or less ellipsoid in shape while the smooth-shell is relatively smooth-surfaced and ovoid to spherical in shape. The two also differ somewhat in quality of kernel. The industry in Hawaii is based on the smooth-shell type, which makes up the entire commercial pack except for small exports of nuts in the shell. The first and main

<sup>1</sup> The work reported herein was conducted jointly by the University of Hawaii and the United States Department of Agriculture at the Hawaii Agricultural Experiment Station. Published with the approval of the Chief, Office of Experiment Stations, United States Department of Agriculture.

<sup>2</sup> Resigned August 16, 1937; now horticulturist of the Hawaiian Macadamia Nut Company.

<sup>3</sup> The writers are indebted to the Hawaiian Macadamia Nut Company for its cooperation in the development of processing methods.

<sup>4</sup> There are relatively few references to scientific investigations on methods of processing commercial nuts. Trade journals, pamphlets of commercial concerns and cooperative marketing associations, personal correspondence, and visits to various factories have comprised the chief sources of reference. Of especial importance in the development of methods of processing the macadamia was the work of Cruess and his associates at the California Experiment Station.

<sup>5</sup> MAIDEN, J. H., AND BETCHE, E. Proc. Linn. Soc. New South Wales, vol. 21 (ser. II, vol. 11) pp. 624-625, 1897.



section of the bulletin pertains to the processing methods and machinery that have been developed primarily for the smooth-shell type, while in a later section the processing of the rough-shell nut is briefly discussed.

The purchase of nuts from growers on the basis of quality, while not specifically concerned with processing, has direct application to factory procedure and is reviewed herein. A more comprehensive report on this phase of the investigation has already been published.<sup>1</sup>

## PROCESSING OF THE SMOOTH-SHELL MACADAMIA

### HUSKING

The nuts borne by a single tree mature over a period of several months, and are harvested when they fall to the ground. During the peak of the drop, nuts should be gathered two or three times a week to avoid loss from rats or from molds. When the drop is light, however, such frequent collections may not be profitable. During wet weather collections should be more frequent than during dry periods. Nuts left lying on the ground longer than 1 week may deteriorate appreciably in quality.

The mature nut is encased in a fibrous green husk which ranges from one-eighth to one-fourth inch in thickness (fig. 1). When unhusked nuts are gathered in heaps or placed in large bags, the temperature of the interior rises rapidly. It has been observed that an increase of 18° F. above room temperature may develop within 10 hours under such conditions. If continued over several days, this treatment is ideal for the development of molds and other organisms, and may affect the flavor of the kernel. The kernels may be normal in appearance but have a musty flavor when processed. If nuts cannot be husked within 24 hours after harvest, they should be spread in thin layers, 2 or 3 nuts deep, on trays or dry floors, under cover, and occasionally raked or stirred.

Of the various implements for hand-husking, probably the most efficacious are a large wooden block set on end and a wooden mallet which loosens the husk with little danger of cracking the

<sup>1</sup> RIPPERTON, J. C., MOLTZAU, R. H., AND EDWARDS, D. W. METHODS OF EVALUATING THE MACADAMIA NUT FOR COMMERCIAL USE AND THE VARIATION OCCURRING AMONG SEEDLING PLANTINGS. Hawaii Agr. Expt. Sta. Bull. 79, 1938.

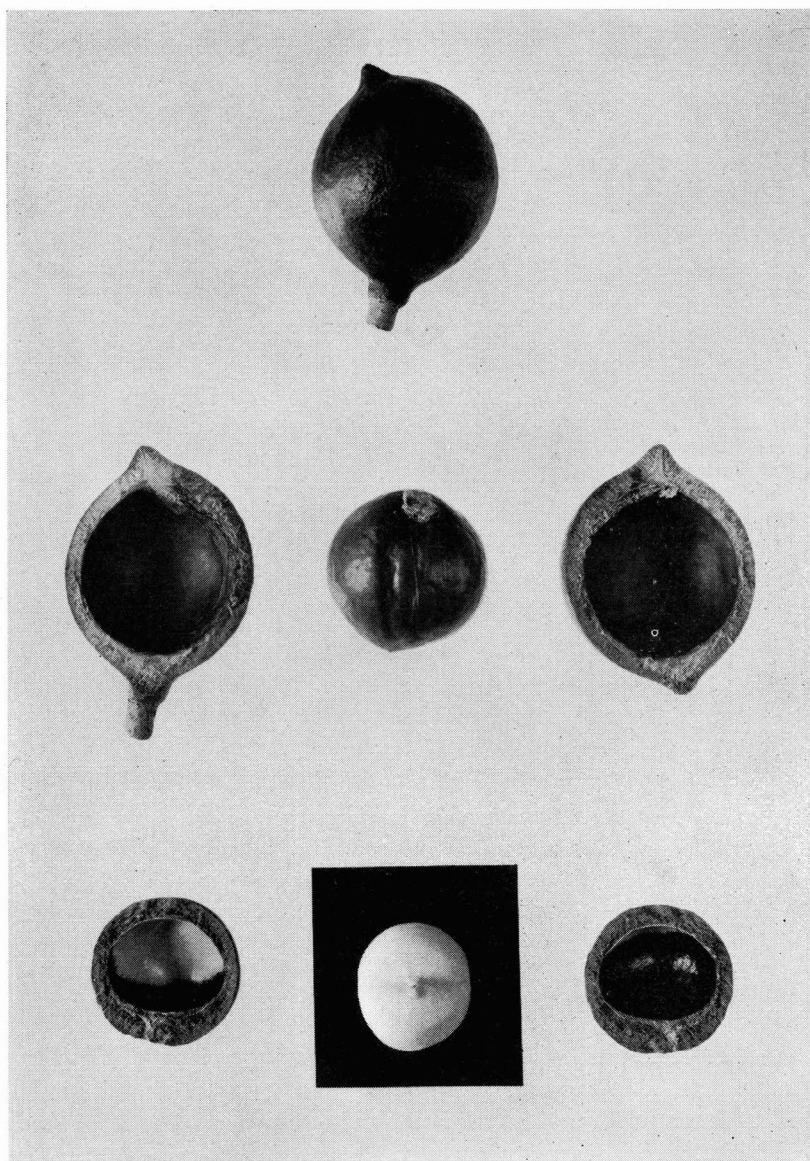


FIGURE 1. — Macadamia, smooth-shell type: Top, unhusked nut; middle row, the husked nut with the two halves of the husk; bottom row, the shelled kernel with the two halves of the shell, showing thick fibrous nature of shell.

nut. At best, however, hand methods are time-consuming, and the use of a mechanical husker is preferable. Power-driven huskers which automatically feed, husk, and separate the nut have been developed for handling large quantities (fig. 2). Home-made huskers suitable for small quantities may be constructed at little expense and are great improvements over hand methods. Such huskers usually employ a revolving and a stationary part, as in a hand mill; the plates are set about 1 inch apart but are adjusted to accommodate various sizes of nuts.

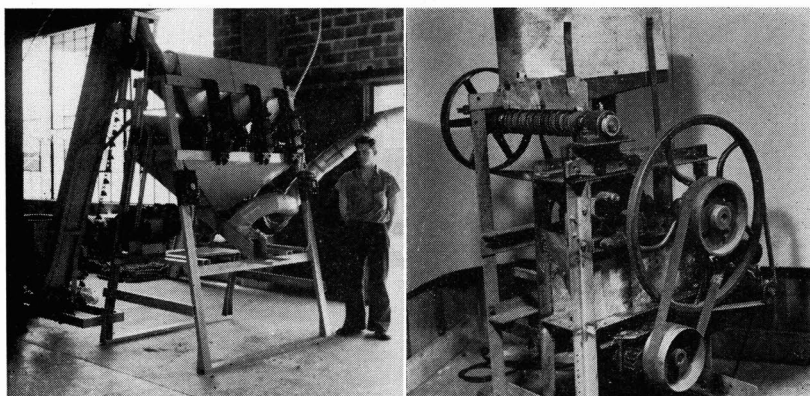


FIGURE 2. — Macadamia husking machines. The freshly gathered nuts are emptied into a hopper and conveyed to the revolving rasp, which forces the unhusked nuts against a shoe or plate held at a tension by coil springs. As the nuts and husks drop from the husking unit, they are automatically separated. Left, courtesy of Hawaiian Macadamia Nut Co.; right, courtesy of Honokaa Sugar Co.)

### DRYING

When the macadamia falls from the tree, the kernel normally contains as much as 25-percent moisture and fills the entire shell cavity. As the nut dries, however, shrinkage occurs and the kernel acquires a crisper texture and the characteristic mild, nutty flavor. It has been found that the macadamia can most easily be cracked, with a minimum of damage to the kernel, when reduced to a moisture content of about 3.5 percent. Various experiments have been conducted to determine the most desirable methods and conditions for drying the nut to this moisture content.



*Air drying*

Air drying of the freshly husked nuts is satisfactory and economical if certain precautions are followed. The nuts should be spread, 2 or 3 deep, on wooden trays with bottoms of 2- to 4-mesh wire cloth. To conserve space, the trays may be placed in tiers, about 10 inches apart. A tray 4 by 8 feet will hold about 200 pounds of nuts. In localities where showers are frequent, the nuts should be kept under cover. If the sides of the building are open or slatted, air circulation may be adequate; otherwise large electric fans to circulate the air are necessary. The nuts should be stirred or mixed at least once a day to facilitate drying.

Under relatively warm, dry conditions existing in Honolulu and other similar localities, air drying is complete in 2 to 3 weeks. In orchards located in the moist uplands, with cool temperatures and relatively high humidities, drying becomes difficult and, when combined with delayed husking, may impair the quality of the nuts. Under such conditions, nuts may be shipped promptly to a central factory for drying, or a large grower or group of small growers may use a husker and drying shed at a nearby low, dry location. As much of the moisture dries out rapidly, it is often feasible to provide facilities at the orchard for partial drying of the nuts before shipping to a factory for final processing.

Air drying can reduce the nuts only to a moisture content in equilibrium with the relative humidity of the air. When the relative humidity is high for a protracted period, nuts do not dry properly and previously dried nuts reabsorb moisture from the atmosphere. For example, at a humidity of 50—a dry day for Hawaii—the moisture-content equilibrium is about 3 percent; at a humidity of 90, which is not unusual, the nuts would not dry below 11-percent moisture.

In order to determine the exact moisture contents of the macadamia in equilibrium with air at various humidities, kernels were placed in a series of jars containing sulphuric acid and water mixtures. Figure 3 shows the moisture contents of the kernels after they had reached equilibrium. From this experiment it may be deduced that air drying is not effective in reducing the moisture content of the kernels to the most desirable percentage for cracking (3.5 percent) at relative humidities above 60.

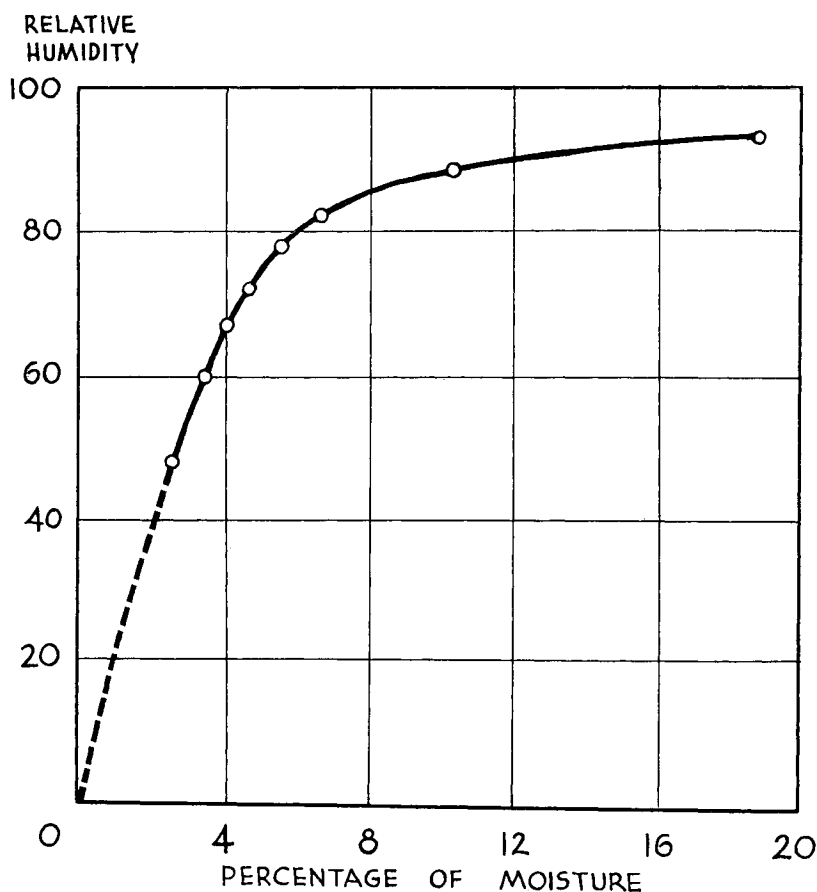


FIGURE 3. — Percentage moisture of macadamia kernels in equilibrium with air at various relative humidities.

While air drying is satisfactory under favorable conditions and results in kernels of excellent quality, it has several disadvantages: The space required; the manual labor necessary in handling the trays, spreading, and stirring the nuts; and the disruption of the factory schedule of operations during periods of high humidity.

#### *Sun drying*

Sun drying is a method commonly used in arid climates, and consequently would not be feasible in many localities in Hawaii.

It might be suitable in the dry leeward sections if protection from sudden showers, such as a movable roof, were provided.

Experiments with sun drying of the macadamia were conducted, with surprisingly good results. Nuts placed in a wire-bottomed tray and exposed to the direct rays of the sun dried to a kernel moisture content of 2.8 percent in 1 week. The processed kernels were of excellent quality, equal to or better than those which had been air-dried. For an as yet unexplained reason, about 25 percent longer cooking time was required for sun-dried kernels to reach a standard degree of brownness at a given temperature than was required for air-dried kernels. Kernels dried with artificial heat also require a longer cooking time, so the phenomenon is doubtless related to the rate of drying.

### *Artificial drying*

Although artificial drying is only necessary under adverse conditions, the initial cost of a hot-air drying machine and the fuel costs may often be offset by economy of time, uniformity of product, and maintenance of a more regular schedule of factory operations.

Figure 4 illustrates a stack dryer, constructed to determine the rate of drying of the macadamia with heated air. For each test the machine was filled to capacity (about 250 pounds) with freshly harvested, husked nuts. At approximately 12-hour intervals the charge was withdrawn and weighed, and samples were taken for moisture determination.<sup>1</sup> The remainder of the nuts were stirred and replaced in the dryer. Tests were made at various temperatures and rates of air flow. In figure 5, the curves showing rates of drying of nuts at different temperatures indicate that the initial loss of moisture is rapid, but the rate is less as the moisture content decreases. The straight line drawn across the drying curves represents the points at which the kernels reach the desirable moisture content of 3.5 percent. Increased temperatures result in marked decreases in drying time.

Due to the small size of the drying chamber, no attempt was made to control relative humidity by recirculating the air,

<sup>1</sup> Where laboratory facilities are available, the moisture in macadamia kernels may be readily determined by the toluene distillation method as described in the A. O. A. C., *Methods of Analysis*, 4th edition, p. 335. Due to the relatively low moisture content, about 50 grams are necessary for an accurate determination. Except with vacuum, oven-drying is not very satisfactory.



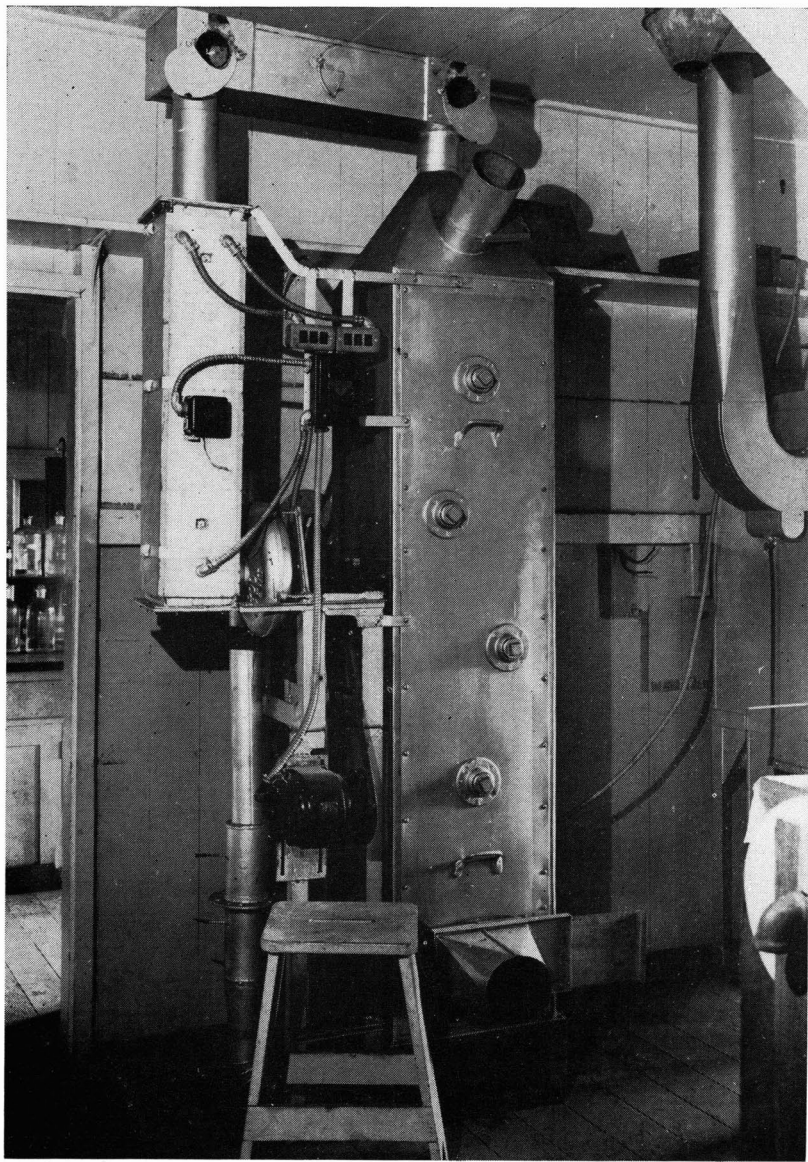


FIGURE 4.— Experimental stack dryer. The nuts are fed into the drying stack at the upper orifice and removed at the lower.

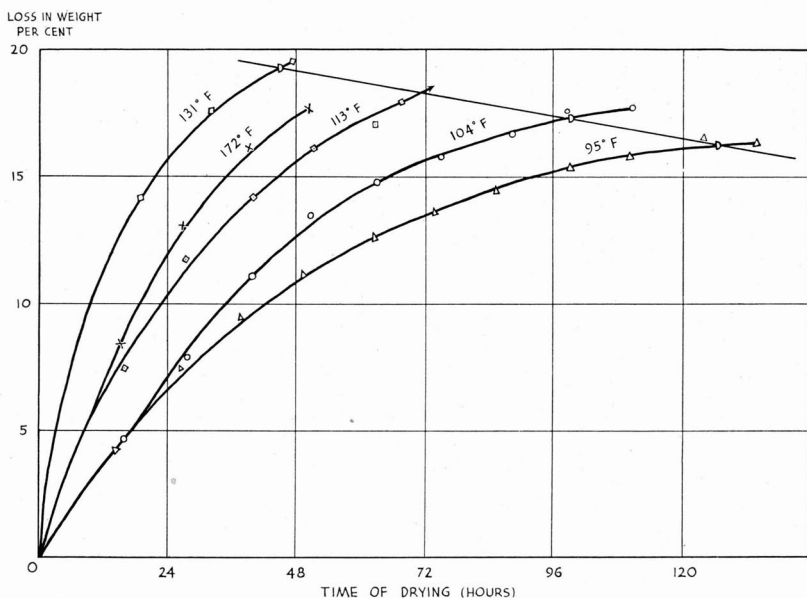


FIGURE 5.—Relation of temperature to rate of loss of moisture in the unshelled macadamia.

although this would be an important factor in the economical operation of a large dryer, particularly at high temperatures.

Cracking, cooking, and organoleptic tests on artificially dried nuts indicated that the final product was of excellent quality. The highest temperature employed (172° F.) apparently had no ill effects on the kernels.

The unshelled macadamia showed little tendency to wedge in a column in the experimental dryer and the kernel was not damaged by rather rough handling in the conveyor. These conclusions led to the design of a commercial-scale dryer with a vertical-column drying chamber, in which all handling of nuts was mechanical. Figure 6 shows the dryer now in use at the local factory; the drying compartment, 4 feet square by 6 feet tall, holds 2 tons of unshelled nuts (1 cubic foot of nuts weighs about 40 pounds). Early in the drying process, relatively low temperatures appear to be economical, while higher temperatures will hasten the final drying, or the whole process may be adjusted in accordance with factory demands.

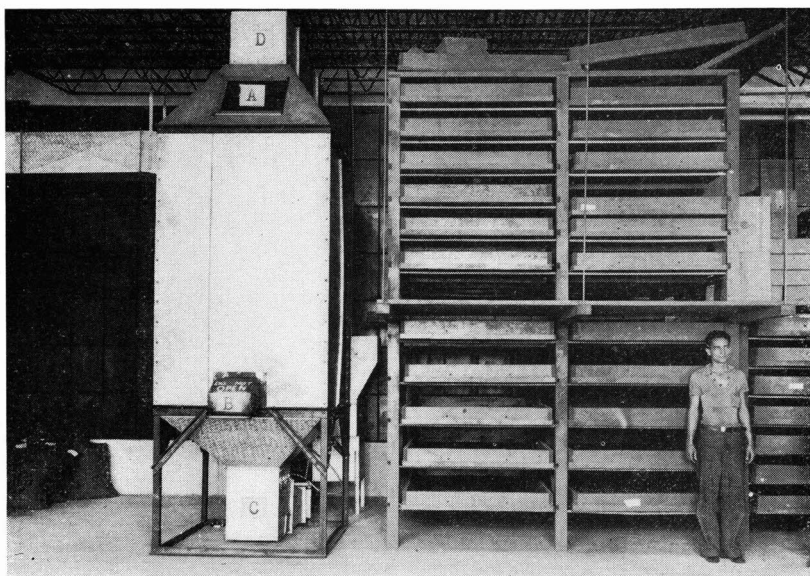


FIGURE 6. — Left - Stack driver, using artificial heat: *A*, Inlet where green nuts are introduced by a conveyor; *B*, outlet where dried nuts are removed; *C*, electric coils which heat the air; *D*, recirculation duct which leads down through the fan and back through the heating coils. Right - Air drying, on trays.

### CRACKING

Differences in size and shape of nut, and in thickness and texture of shell, present many difficulties in developing a cracking machine adapted to this nut. With present machines, a small amount of hand work is still required in the extraction. The chief problem is to crack the shells without damage to the tender, brittle kernels. The shells are extremely hard and vary from one-sixteenth to one-fourth inch in thickness, with the thicker shells predominating. The shell, therefore, presents an armor-like coat with about one thirty-second inch clearance between the kernel and shell. When the macadamia is struck a sharp blow, the tough shell tends to crack only partially, and a portion is often forced inward, damaging the kernel. Owing to great variability in thickness and hardness of shell, cracking by hand is not successful. An iron vise is more effective than a hammer if whole kernels are desired but is too time-consuming for commercial use.



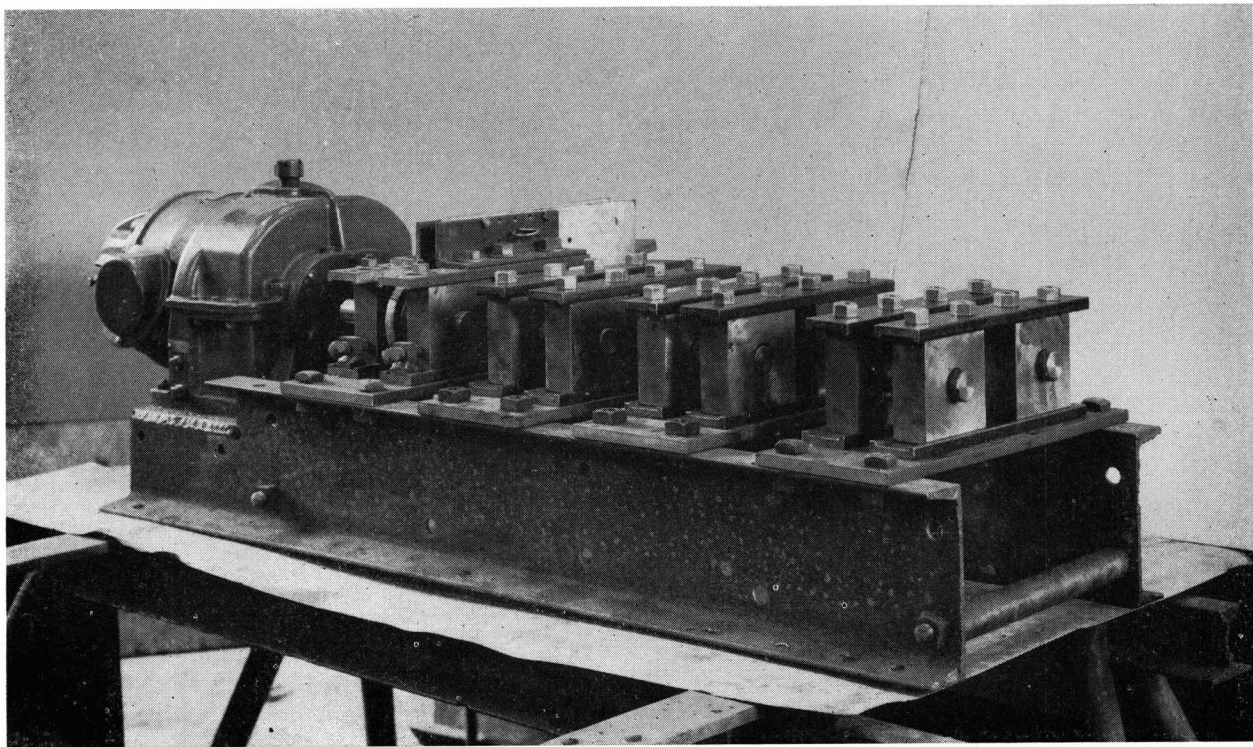


FIGURE 7.— A series of cracking machines, adjusted to various sized nuts. (Courtesy of Honokaa Sugar Co.)

Considerable time has been spent in developing commercial cracking machines. The first model used a circular saw which cut the shells into halves without touching the kernels. Due to cost of construction, power requirements, and mechanical imperfections, this model was soon discarded. New crackers of relatively simple design and low power requirements, which employ the principle of the vise, have since been put into use (figs. 7 and 8). The nut is held between two blunt movable wedges, and the shell is cracked into clean halves. An efficiency of 96 percent (i.e., whole kernels free from the shell) has been obtained with this type of machine.

The crackers, adjusted to various sizes of nuts, may be part of a large unit. A modified centrifugal machine loosens the kernels within the shells, a sizing machine sorts the nuts and feeds the various sizes to their respective crackers, the cracking machines force open the shells, and an automatic separator shakes out the loosened kernels. Kernels which adhere to the shell are separated by hand. The unit handles about 2 tons of air-cured nuts in 8 hours.

#### QUALITY GRADING

Dried macadamia kernels disclose marked differences in appearance which are reflected in the quality of the cooked product. The commercial grading of kernels is based on the findings of this station,<sup>1</sup> that plump, smooth-surfaced, light-colored kernels have high oil content and low specific gravity (i.e., are relatively light). As the oil content decreases, the kernels are heavier, darker in color, and less mild in flavor. Figure 9 presents the observed qualities of groups of macadamia kernels selected on the basis of specific gravity and percentage of oil.

These observations have led to a simple method of commercial grading by using specific-gravity solutions. Grade 1 may be considered to comprise all kernels so light as to float in tap water at room temperature, having a specific gravity of approximately 1. Such kernels are consistently plump, smooth, and light-colored, and roast uniformly with a mild flavor.

Grade 2 kernels, while variable in quality, may be sold to the confectionery and baking trades. The specific gravity of this

<sup>1</sup> RIPPERTON, J. C., et al., previously cited.

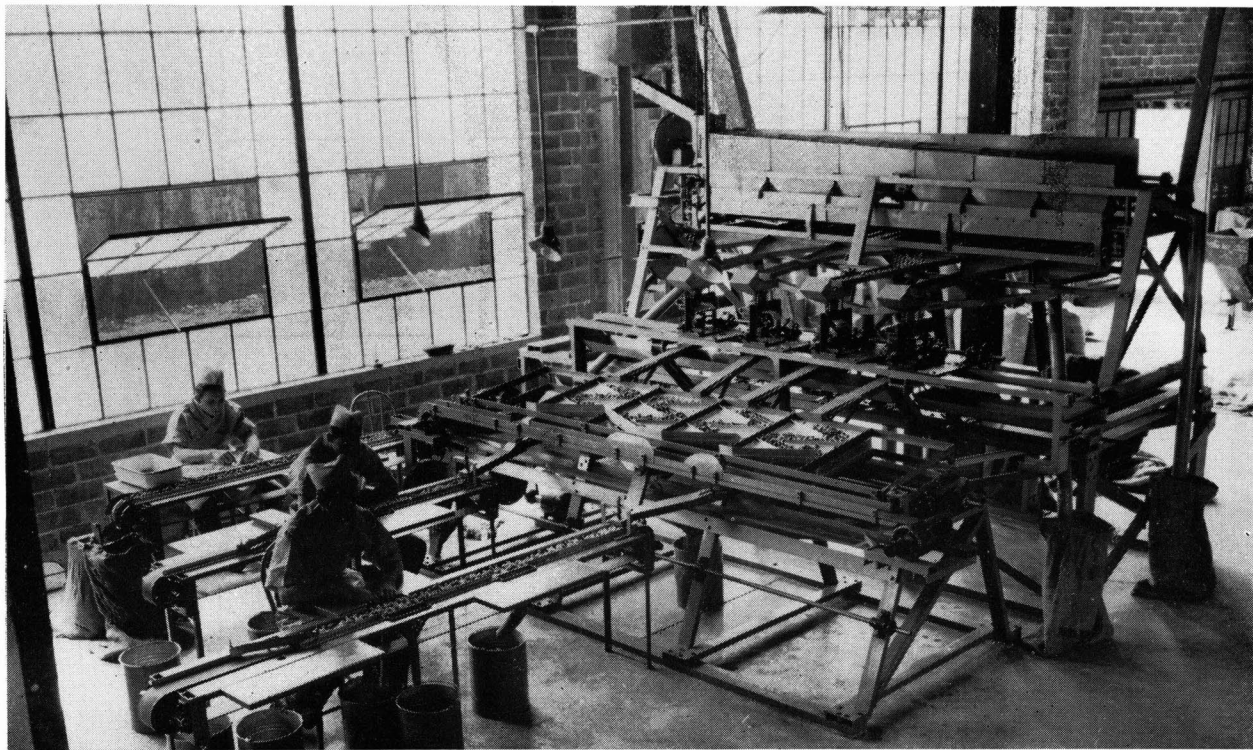


FIGURE 8. — Cracking machines mounted on a large unit — the loose kernels are automatically separated from the shells and pass on to endless belts where broken or off-color pieces and shells which adhere to the kernel are removed. (Courtesy of Hawaiian Macadamia Nut Co.)



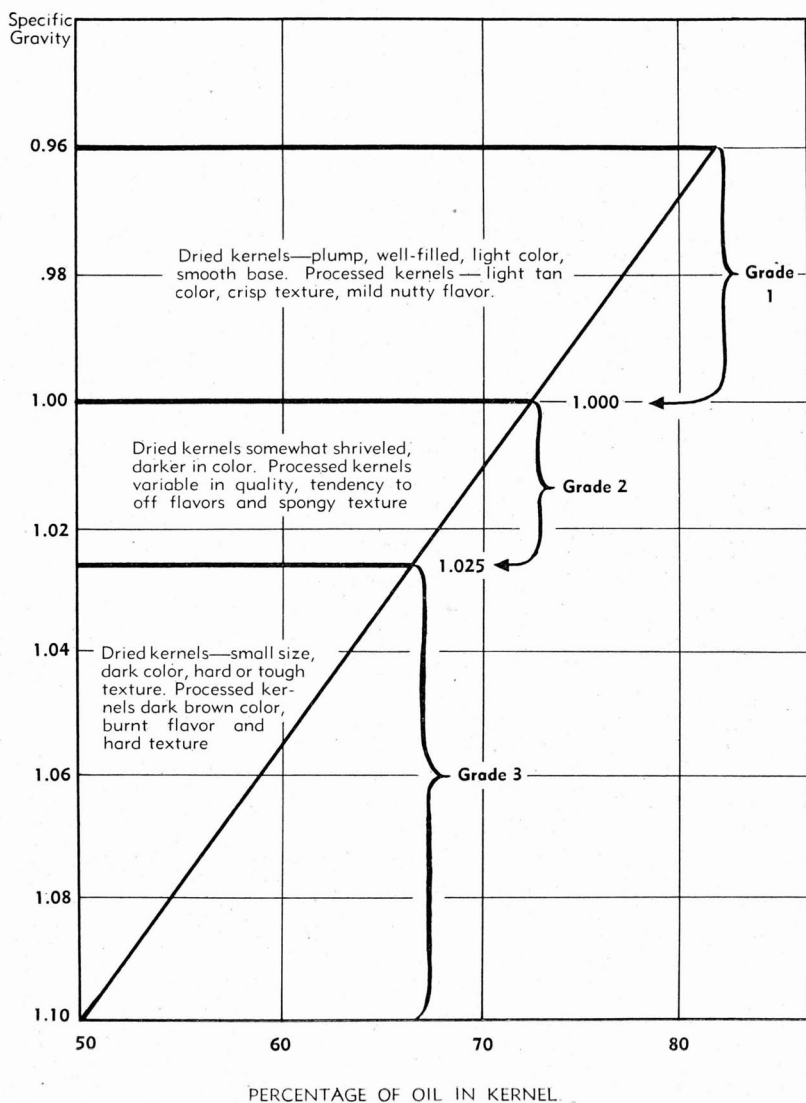


FIGURE 9.—Relation of kernel quality to specific gravity and percentage of oil.

group is between 1 and 1.025. A convenient solution to use is made up of  $5\frac{1}{2}$  ounces of sodium chloride (table salt) per gallon of water. Kernels which sink in this solution are classed as grade 3, and are generally discarded.

The procedure of grading is simple. Air-dry kernels are immersed in the first solution and stirred vigorously to free them of air bubbles. The kernels which float (grade 1) are skimmed off and dried, first by draining, then by centrifuging. The kernels which sink in the first solution are immersed, after draining, in the second, salt solution and the floating grade 2 kernels are skimmed off and dried. All kernels which sink in the salt solution are classed as grade 3 (fig. 10).

During grading, the kernels reabsorb moisture up to about 8 or 10 percent; this is removed by dehydration before further processing.

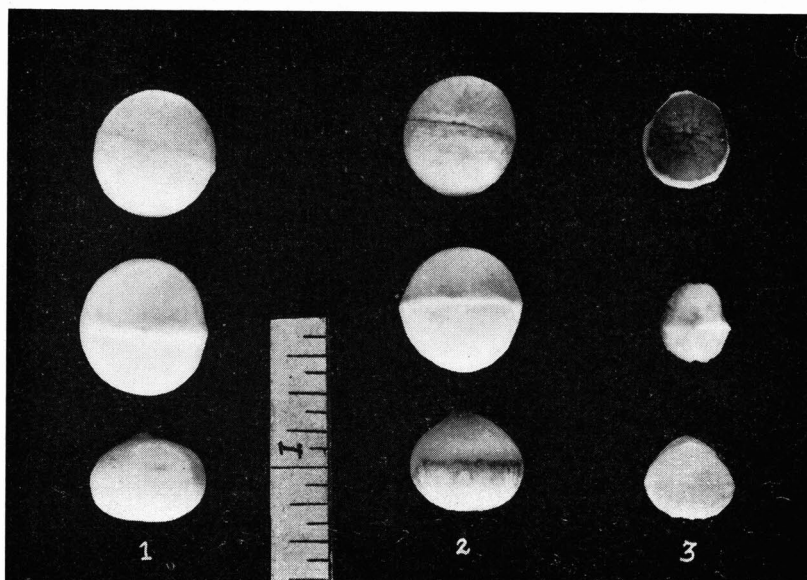


FIGURE 10. — Grades of macadamia kernels, showing (top to bottom) apical, basal, and side views:<sup>1</sup> (1) Grade 1—large, plump, white kernels; (2) Grade 2—moderate shrinkage and partial discoloration; (3) Grade 3—badly shriveled kernels with much discoloration.

<sup>1</sup> While the observer would assume that the flattened portion of the nut was the base, it is actually the apex.

### DEHYDRATION

Oil cooking, and oven roasting to a less extent, require kernels of a lower moisture content than that at which the nuts were cracked. Moist kernels do not acquire a crisp texture and, when cooked in oil, tend to become rancid. A moisture content of 1.5 percent has been established as most desirable for macadamia kernels.

Dehydration of the kernels may be accomplished in a very slow oven with the door slightly open. A wire tray made of screening or hardware cloth permits air circulation and facilitates drying. Dehydrated kernels are distinctly harder in texture than the raw nuts, but, unless the oven temperature has been too high, they should not have changed color.

For large-scale operations a tray dehydrator has been designed in which provision for heating and recirculation of the air is made (fig. 11). It has been found that a low initial temperature (about 110° F.), maintained until the kernels have been partially dried, prevents them from acquiring a boiled appearance. As soon as excess moisture acquired during grading has been eliminated, the temperature may be raised to and maintained at 170° F. A maximum of about 8 hours is required to reduce the kernels to a moisture content of 1.5 percent. After drying, the broken pieces are usually graded out, and the kernels are ready for the final stage of processing.

### COOKING

Two general methods of cooking kernels are employed—immersion in a vat of hot oil and roasting in an oven. The unusually high oil content of macadamia kernels (70 to 80 percent as compared with 50 to 60 percent for almonds) makes them adaptable to oven roasting. A heat of 275° F. for 40 to 50 minutes has been found to produce the most desirable rate of roasting; higher temperatures cause the surface of the kernel to brown rapidly while the center may remain uncooked. Except in specially constructed ovens, the uneven distribution of heat necessitates frequent stirring to produce a uniform product. Wire screen trays may be used to aid air circulation and to prevent scorching.

Many experiments designed to compare the flavor, color, texture, and consumer-preference of oil-cooked and oven-roasted

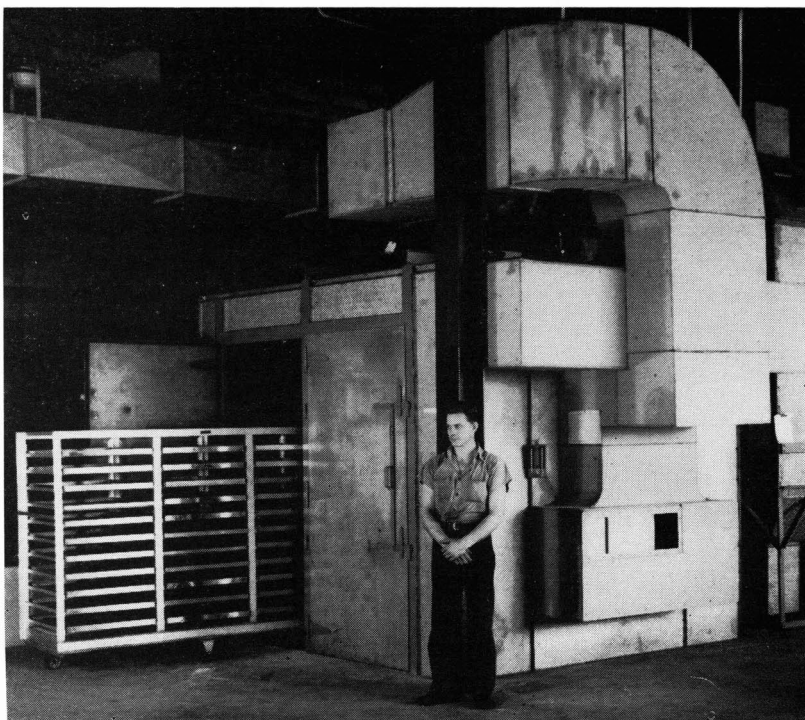


FIGURE 11. — Macadamia dehydrator.

macadamia kernels have led to the commercial adoption of the former process. In flavor and texture of grade 1 kernels there is little difference between the two methods, but grade 2 kernels become harder with oven roasting. In appearance the oil-cooked product is distinctly superior, having a uniform, attractive, golden-brown color, while oven-roasted kernels are much duller.

Temperature and time are important factors in the oil cooking of the kernels. With too high temperatures the cooking is uneven; with too low temperatures the product becomes oil-soaked. For the macadamia, oil cooking at a temperature of  $275^{\circ}$  F. for 12 to 15 minutes has been found most satisfactory. The process is adjudged complete when the kernels have reached an established stage of brownness.

Inasmuch as copper, brass, aluminum, and to a less extent tin, zinc, and galvanized iron are corroded by hot oil, monel metal,

glass, or stainless steel are recommended for the cooking vat and baskets. A refined coconut oil has been prepared especially for nuts and is now being used in commercial processing of the macadamia as well as many other nuts. Care must be taken to remove particles of kernels which tend to darken the oil and reduce its effective life. It is estimated that approximately 13 gallons of oil are required for 1,000 pounds of kernels. Mechanical agitation of the oil or frequent stirring of the kernels is required to maintain an even temperature and yield a uniform product. The heat is increased as each new charge is added, so that the cold kernels will not reduce the temperature of the oil below 275° F.

When cooking is completed, the wire basket in which the kernels were immersed in the oil is lifted from the vat and allowed to drain. The kernels are placed in a centrifuge which removes excess oil, and then spread on wire-mesh trays through which air is passed to effect rapid cooling.

The salting technique is important and follows when the kernels are lukewarm to cool. An adhesive is applied before salting—for oven-roasted kernels a 15-percent water solution of gum arabic or for oil-cooked kernels a special oil which melts at about 90° F. The kernels are spread in a thin layer and stirred or shaken as the adhesive is sprayed over them with an ordinary spray gun. Salt is applied immediately. A special grade of salt, of medium grain and free from impurities, is recommended. The adhesive solidifies on the surface of the kernel as room temperature is reached, and holds the salt grains.

For oil cooking at home, an excellent product may be made by substituting any of the common salad oils for coconut oil. Salting may be accomplished by brushing the cooled kernels with butter before sprinkling them with table salt. Aluminum utensils should not be used. A thermometer is essential.

Because cooked kernels absorb moisture readily, packing should proceed as soon as the kernels are salted and cooled. Vacuum packing has become an almost universal practice. Except at unusually high temperatures, vacuum-packed kernels will keep without deterioration for several years. Figure 12 shows the room at the local factory in which these final processing stages are conducted.

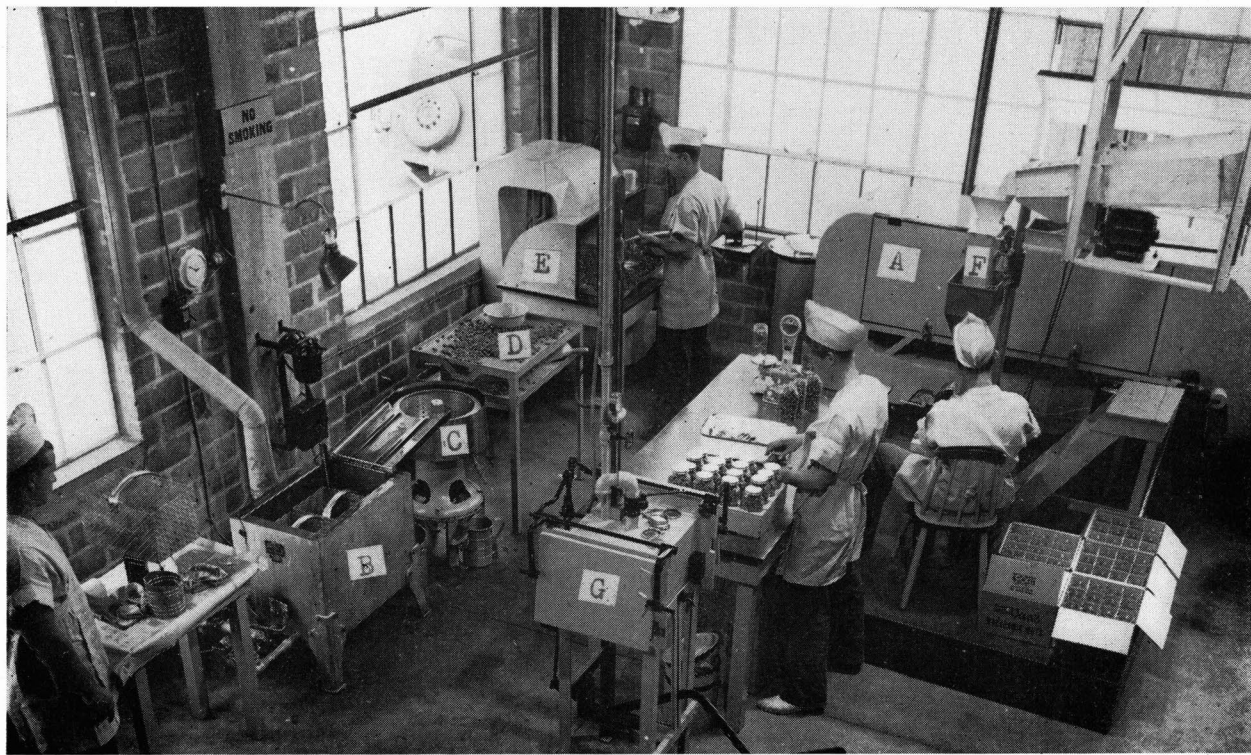


FIGURE 12.—Dehydrating, cooking, and packing room at the local factory: A, Tray dehydrator; B, oil cooker; C, centrifuge for removing excess oil; D, cooling tray; E, salter; F, bottle; G, vacuum sealer.



## STORAGE OF FRESH KERNELS

Experiments with fresh nuts, either unshelled or as extracted kernels (walnuts, pecans, almonds, and peanuts), have demonstrated that the nuts may be held for several months without special precautions except to be kept cool and dry. Under warm, humid conditions such commercial nuts are subject to rather rapid deterioration, usually because of the development of molds and of rancidity. Cold storage has been found effective in preserving the quality of the nut over periods as long as 12 months. Storage under vacuum, or with various inert gases such as nitrogen and carbon dioxide, appears to have little advantage over ordinary cold storage over a similar period.

Thus far the storage of the macadamia has not been a problem in the Territory, as the current demand far exceeds the supply. The rapid increase in production may eventually make storage facilities necessary. Even under present conditions, a limited amount of storage is necessary if a 6-month crop is to be processed throughout the year. This would appear to have the following advantages: More efficient utilization of labor and machinery, lower investment in bottles and cases, more flexibility in anticipating the type of pack desired, and a fresher product.

Inasmuch as the macadamia is seldom sold as an unshelled nut, storage problems will probably center around the holding of extracted kernels at some stage of processing, for relatively short periods. To gain some information on this problem, a test was conducted to determine the effects of storage on five lots of macadamia, treated as follows:

- |       |                                           |
|-------|-------------------------------------------|
| Lot A | Unshelled air-dried nuts in burlap sacks  |
| Lot B | Air-dried kernels in open containers      |
| Lot C | Air-dried kernels in sealed containers    |
| Lot D | Dehydrated kernels in sealed containers   |
| Lot E | Oven-roasted kernels in sealed containers |

The sealed containers were not vacuumized. Each lot was tested under five storage conditions: (1) Cold storage—20° F.; (2) cold storage—32° F.; (3) cold storage—40° F.; (4) normal temperature (averaging about 70° F.), high relative humidity—orchard at Nutridge, Oahu; and (5) normal temperature (averaging about 80° F.), low relative humidity—factory in Honolulu.

TABLE 1.—Effect of storage under different conditions on the quality of the macadamia<sup>1</sup>

Temperature of storage	LOT A			LOT B			LOT C			LOT D			LOT E		
	Tex- ture	Fla- vor	Color	Tex- ture	Fla- vor	Color	Tex- ture	Fla- vor	Color	Tex- ture	Fla- vor	Color	Tex- ture <sup>2</sup>	Fla- vor <sup>2</sup>	Color
<i>Degrees F.</i>															
					After 3 months' storage										
20	1	*	1	3	*	3	2	2	3	1	1	1	2	2	1
32	1	*	1	3	*	3	2	2	3	1	1	1	2	2	1
40	1	*	1	3	*	3	1	1	3	1	1	1	1	1	1
70 (Nutridge)	1	†	1	1	2	2	3	3	3	1	2	1	1	1	1
80 (Factory)	1	1	1	1	1	1	3	3	3	1	2	1	1	1	1
					After 6 months' storage										
20	1	*	3	3	*	3	2	2	3	1	1	1	2	2	1
32	1	*	3	3	*	3	2	2	3	1	1	1	2	2	1
40	2	*	3	3	*	3	2	2	3	1	1	1	1	2	1
70 (Nutridge)	2	†	3	3	3	3	3	3	3	1	2	1	2	2	1
80 (Factory)	1	1	2	3	3	2	3	3	3	1	2	1	2	2	1
					After 12 months' storage										
20	2	*	3	3	*	3	2	2	3	1	1	1	2	2	1
32	2	*	3	3	*	3	2	2	3	1	1	1	2	2	1
40	3	*	3	3	*	3	3	3	3	1	1	1	2	2	1
70 (Nutridge)	3	†	3	3	†	3	3	3	3	2	†	3	2	†	1
80 (Factory)	2	†	2	3	3	3	3	3	3	2	†	3	2	†	1

<sup>1</sup> Key to ratings—

Texture (uncooked)

1. Crisp, tender.
2. Loss of crispness, somewhat mealy.
3. Tough or soggy.

Flavor (uncooked)

1. Mild, nutty, equal to fresh nuts.
2. Loss of fresh flavor, flat and insipid.
3. Poor, not edible.

Color (after cooking)

1. Light golden brown.
2. Dull brown and uneven, splotchy.
3. Dark brown.

<sup>2</sup> Kernels cooked before storage

\* Absorbed cold storage odors.

† Rancid.

Samples of each lot under each storage condition were tested as to texture and flavor of the uncooked kernel and color of the cooked kernel at the end of 3, 6, and 12 months. The results are summarized in table 1, on the preceding page.

Deterioration in flavor may be due to absorption of cold storage odors, development of rancidity, or merely to a gradual loss of the delicate, nutty flavor which makes the macadamia so highly prized as an edible nut. The need of special storage rooms to prevent the absorption of odors is generally recognized, and some investigators recommend air circulation for air-dried kernels stored in open containers. Rancidity results primarily from high temperature. Moisture apparently has little effect since there is no marked difference between the nuts stored at the factory and at Nutridge, and since rancidity developed in the dehydrated and in the roasted samples. Gradual loss of flavor, until the kernel becomes flat and relatively tasteless, is not restricted to the macadamia but is often noted in the storage of other nuts. Over long periods, this may occur to such an extent that the kernels are no longer edible.

Deterioration in texture appears first as a loss of crispness and a slight mealiness. In time the kernel loses all resemblance to its original texture and becomes either tough or soggy. Break-down of tissue may also be considered a form of texture deterioration, but inasmuch as it becomes evident only after the kernel is cooked, it has been tabulated under color changes. A kernel, perfectly normal in appearance, may be almost black when cooked. Break-down of tissue causes a brownish splotchiness of the cooked kernel, often on bruised surfaces and unevenly penetrating the interior. With increased time of storage the whole kernel is affected and cooks to a dark brown color throughout. The pronounced differences in color of cooked kernels stored under various conditions are evident in figure 13. In the kernels cooked before storage, no color change was evident.

It is obvious, from table 1, that if the macadamia is to be stored for periods longer than 3 months, the form to be recommended would be the dehydrated kernel, held in cold storage in a sealed container. Air-dried nuts, either shelled or unshelled, should keep, in a dry location, for at least 3 months. Occasional inspections should be made, however, for signs of deterioration.

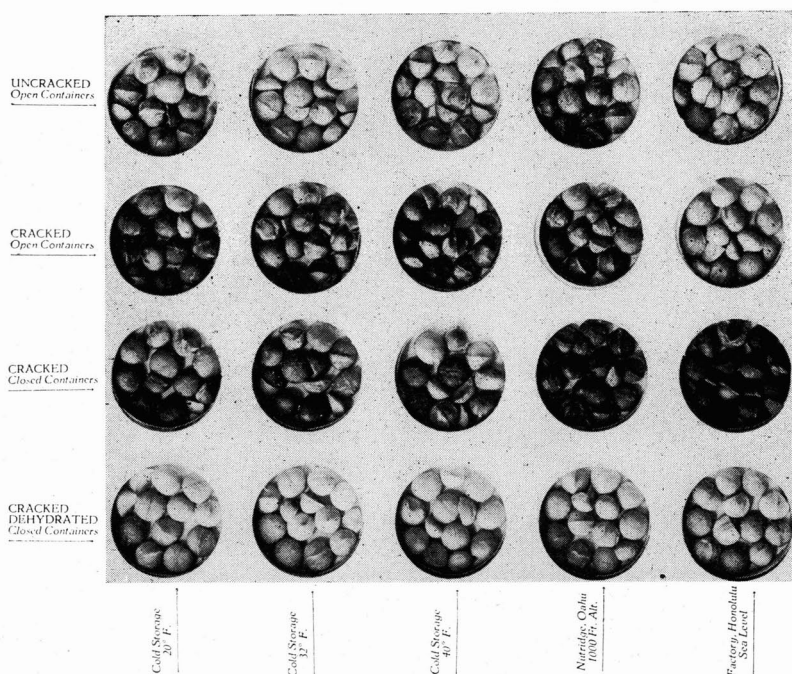


FIGURE 13. — Break-down of tissue of the macadamia, after 6 months of storage, as evidenced by the color of the kernels after cooking. (Note the uniformly good color of the dehydrated series).

Cooked kernels in sealed containers, in contrast to the dehydrated kernels, deteriorate more rapidly in cold storage. If they are to be held for longer than 3 months, they should be vacuum-packed. Considering the relatively small bulk and high value of the product, cold storage of the dehydrated kernels adds little to the cost of processing, and would appear to offer many advantages. The kernels are then ready for cooking and packing at any time.

Where cold storage and dehydration facilities are not available, a practical storage method is to hold the well-dried kernels in an airtight drum, equipped with a loose-fitting false bottom of wood. Underneath this false bottom and above the kernels are placed pans of calcium chloride, a drying agent, which may be changed when necessary.

## INSECT CONTROL

The nut borer (*Argyroploce illepidata*), which develops in the husk of the macadamia before the nut falls from the tree, is occasionally a problem, although removal and destruction of the husks and liberation of the parasites eliminate practically all the borers. Certain meal moths are also known to attack the nut in storage. Infestation may become severe, particularly when extracted kernels are stored at room temperatures.

For practical purposes, husking immediately after harvesting and rapid drying reduce insect infestation to a negligible amount. The temperature employed for dehydration is generally high enough to kill all weevils as well as eggs, or storage at a freezing temperature for a short period is effective.

SUMMARY OF RECOMMENDED COMMERCIAL METHODS OF  
PROCESSING THE MACADAMIA

*Husking* — Husk within 24 hours of harvesting, or spread nuts in a thin layer in wire-bottomed trays to dry. Do not hold green, unhusked nuts in sacks or bins.

*Drying* — Place husked nuts, in layers 2 or 3 deep, on wire-bottomed trays. Dry locations and good air circulation are necessary. Air drying to 3- to 4-percent moisture content should take between 2 and 3 weeks and sun drying about 1 week; with artificial heat, the drying period may be reduced to 3 to 5 days.

*Cracking* — Remove shells from kernels by mechanical crackers in order to secure a maximum of whole kernels at a minimum cost.

*Quality Grading* — Separate the kernels into three grades (grade 1, specific gravity less than 1; grade 2, specific gravity 1 to 1.025; and grade 3, specific gravity greater than 1.025) by immersion in water and in a salt solution. Use only grade 1 kernels for packing.

*Dehydration* — Reduce graded kernels to a moisture content of 1.5 percent in a forced-draft oven with an initial temperature of 110° F. and a final temperature of 170° F. About 8 hours are required.

*Cooking* — Roast dehydrated kernels in an oven at 275° F. for 40 to 50 minutes, or, preferably, cook in a vat of refined coconut oil at 275° F. for 12 to 15 minutes.

*Salting* — When the cooked kernels are just warm to the touch, spray with an adhesive substance and sprinkle with salt.

*Storage* — If kernels are to be held longer than 1 month before cooking, they should be dehydrated and kept in airtight containers in cold storage at 32° F.

*Insect Control* — Insect infestation may be controlled by prompt husking, drying, and cracking of the nuts, and storage of the dehydrated kernels at 32° F.

## PROCESSING THE ROUGH-SHELL MACADAMIA

### CRACKING

The shell of *Macadamia ternifolia* is generally thinner than that of its botanical variety *integrifolia* and is, therefore, easier to crack. Moreover, the kernel has a firmer texture and there is greater shrinkage during the drying process. Because of their ellipsoidal shape the rough-shell nuts are more easily cracked by hand than the smooth-shell. The present commercial machines, which were designed for spherically shaped nuts, are not so efficient in cracking the rough-shell nuts. In a cooperative test of cracking by hand in the Kona District, it was found that the average rate was 45 pounds of unshelled nuts or 14 pounds of kernels per 10-hour day. In commercial practice, the percentage of broken pieces due to hand cracking and lower quality kernels generally found in rough-shell nuts make hand cracking of questionable economic value.

### GRADING

The rough-shell trees tend to produce smaller percentages of grade 1 kernels. With some trees, practically the entire crop is classified as second or third grade. In general, the early part of the harvest is poor, with the quality improving as the season advances. In a cooperative trial, the first shipments contained less than 50 percent of grade 1 kernels, but the season average, on 2 tons of nuts, was 70 percent grade 1 and 25 percent grade 2 kernels. From the smooth-shell trees an average of 90 percent grade 1 kernels is not uncommon.



The rough-shell kernel is distinctly different from the smooth-shell in texture and flavor — so much so that it would seem inadvisable to mix corresponding grades in the same pack. The rough-shell kernel, either raw or processed, is firmer, and the flavor is noticeably sweeter. In a preference test with 85 persons, 56 (66 percent) preferred the smooth-shell type.

### COOKING

The rough-shell kernel cooks more rapidly than the smooth-shell, and a temperature of 260° F. for 12 minutes is recommended for oil cooking.

### MARKETING

At the present time the market for the rough-shell macadamia is chiefly local, most of the crop being sold as unshelled nuts. The low demand, which has been in part due to poor quality, might be increased by cracking and grading at the orchard.

It is possible that horticultural varieties of the rough-shell type may be selected which will have none of the defects so apparent in the present heterogeneous group of seedling trees. However, at the present time the seedlings of the smooth-shell type produce the preferred commercial product. With both types it is eventually possible that many of the poorer trees may be profitably topworked to high quality varieties.<sup>1</sup>

### EVALUATING THE MACADAMIA ON A QUALITY BASIS

At the present time nuts are bought and sold on the basis of a fixed price per pound of unshelled, partially dried nuts, no consideration being given to the actual value of the nuts on the basis of percentage of grade 1 kernels produced. The station has developed a "quality ratio" method by which the factory price for nuts might be based on the number of pounds of unshelled nuts required to produce 1 pound of grade 1 kernels, taking into account a number of different factors. This method has been described in detail,<sup>2</sup> but is summarized here. Calculation of the quality ratio involves four factors:

<sup>1</sup> BEAUMONT, J. H., AND MOLTZAU, RALPH H. NURSERY PROPAGATION AND TOPWORKING OF THE MACADAMIA. *Hawaii Agr. Expt. Sta. Circ. 13*, 28 pp., illus. 1937.

<sup>2</sup> RIPPERTON, J. C., et al., previously cited.

(1) *Sizing of unshelled nuts* — All nuts with diameters less than 1.6 centimeters ( $\frac{5}{8}$  inch) are eliminated in the sizing machine and discarded as culls. This segregation is based on the smallest size of nut which can be cracked economically with present machinery, but in general the culls are inferior in quality as well as too small to make an attractive pack. The percentage of "sizeable" nuts is calculated, making no distinction among sizes larger than the minimum.

(2) *Moisture content* — Due to differences in degree of drying at the orchard, it has been found that shipments of nuts lose up to 10 percent in weight when dried to the 3.5-percent moisture content desirable for cracking. The relationship between the weight of nuts as received and the weight of the dried nuts is therefore considered.

(3) *Proportion of kernel* — The sizeable nuts are cracked and the proportion of kernels is calculated.

(4) *Grading of kernels* — The kernels of sizeable nuts are graded according to specific gravity, and the percentage of grade 1 kernels is determined. Color standards acceptable to the trade have not been established. Sometimes, apparently due to climatic or nutritional factors, a large proportion of kernels from certain localities have discolored bases and may be discarded during grading.

The formula for the quality ratio may be expressed as follows:

$$\frac{100}{\frac{\text{Percentage of sizeable nuts} \times \text{percentage of dried weight} \times \text{percentage of kernel}}{\text{percentage of grade 1 kernels}}}$$

For example, assuming 90 percent of sizeable nuts, which when dried are 95 percent of their original weight, 30 percent of kernel, and 90 percent of grade 1 kernels; thus:

$$\frac{100}{90 \times 95 (= 85.5) \times 30 (= 25.65) \times 90 (= 23.085)} = 4.33$$

With a quality ratio of 4.33 and an estimated wholesale value<sup>1</sup> of 80 cents per pound for processed nuts, the gross value of 1 pound of unshelled nuts would equal 80 divided by 4.33 or 18.5 cents. Allowing factory overhead of 8 cents per pound, the

<sup>1</sup> All values given for nuts are hypothetical and assumed only for the sake of illustration. The market price and processing costs cannot be estimated with any degree of accuracy until production assumes larger proportions and methods of processing are better developed.

TABLE 2. — Quality ratio of the macadamia and its relationship to the value of the unshelled nuts

Type of macadamia	Location	Sizeable unshelled nuts	Kernels	Grade 1 kernels	Quality ratio	Hypothetical net value per pound of unshelled nuts <sup>1</sup>	Remarks
		<i>Percent</i>	<i>Percent</i>	<i>Percent</i>		<i>Cents</i>	
Smooth-shell	Waipahu, Oahu	90.3	28.7	71.8	5.37	6.9	Crop from July to September, 1935
Do	do	96.0	29.3	95.6	3.72	13.5	Crop from October to December, 1935
Do	Nutridge, Oahu	92.2	29.7	78.9	4.63	9.3	Crop from July to September, 1935
Do	do	93.9	30.2	95.4	3.70	13.6	Crop from October to December, 1935
Do	Keauhou, Hawaii	87.0	34.2	52.4	6.42	4.5	Shipment of November 15, 1935
Do	do	100.0	27.0	86.2	4.30	10.6	Shipment of November 29, 1935
Rough-shell	Kona, Hawaii	<sup>2</sup>	21.7	27.9	16.52	—3.2	Shipment of December, 1935
Do	do	<sup>2</sup>	26.4	53.4	7.09	3.3	Shipment of March 7, 1936
Do	do	<sup>2</sup>	27.0	84.9	4.37	10.3	Shipment of May 25, 1936

<sup>1</sup> Assuming a value of 80 cents per pound of kernel and overhead of 8 cents per pound of unshelled nuts received at the factory.<sup>2</sup> Assuming 100 percent.

price received by the grower should be 10.5 cents. Table 2, taken from actual lots of nuts received from commercial orchards, shows how the net value of unshelled nuts fluctuates. (The loss of weight in drying was not taken into consideration at the time these shipments were tested.)

Although such a method of evaluating commercial shipments has never been practiced, it is believed to be inevitable with rapidly increasing production. A sample not exceeding 1 percent of the shipment should be sufficient for fair price-estimating, but certain practical aspects will have to be considered when a quality-ratio evaluation is inaugurated.